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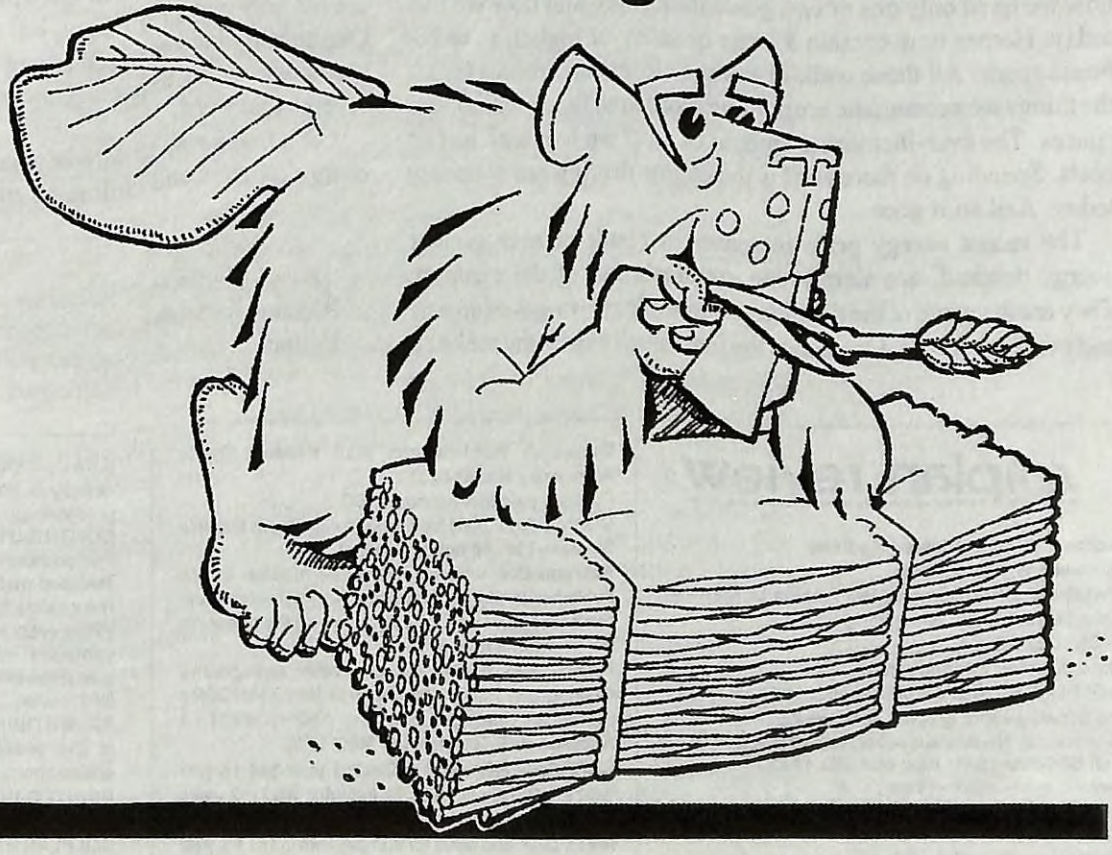
Building with Straw



From the Editor . . .

Today we are facing issues of major environmental and climate change. On the surface, the changes may be too subtle for any individual to feel his or her actions are of consequence. Yet the problem is big. There is no doubt at all that human activity has had and continues to have a major impact on the earth and its ecosystem.

We cannot directly see the impact of changes in the concentrations of CO_2 and other greenhouse gases in the atmosphere. It may seem that winters are getting warmer, but the snow is still flying and Jack Frost is still nipping. And those storms are nasty, but are they not just a part of the natural cycle of nature? So what if there is a bit less ice in the Arctic Ocean, there's a lot still there, isn't there? What can we as individuals do anyway?

Turning off one or two 100 watt bulbs may not seem like much, but if one million or ten million 100 watt lights are switched off, suddenly it starts to make a difference. If every house reduces hot water consumption by just 10 percent, it makes a difference. One could list thousands of similar examples of small, seemingly insignificant ways to reduce resource use.

There is no quick fix solution to the problems we are facing. It has taken us two hundred years to get where we are today. Our wasteful, spendthrift lifestyle has evolved over time. Think about how we lived only one or two generations ago, and how we live today. Homes now contain a large quantity of highclass warehouse space: All those walk-in storage closets and rooms for all the things we accumulate are nothing more than fancy warehouse spaces. The ever-increasing amount of stuff we live with has its costs. Spending on more stuff is the engine driving our economy today. And so it goes.

The recent energy price increases, a result of ever greater energy demand, are simply one manifestation of the changes. They are the result of the shrinking source of easy-to-get-at energy and other resources. One hopes the increases may be the wake up call we need collectively as a society to get our house in order. We are using resources, many non-renewable, at an increasingly fast and unsustainable pace. The solutions are not going to be sudden, but we can only hope they will come quickly enough before irreparable damage is done.

The challenge for our industry is to become more proactive, to practice aggressively what we profess to believe in, but in fact don't always do. I hear much talk about energy efficiency, quality, and affordability. No doubt, we do build good quality, fairly energy efficient new homes that are affordable by some. Yet when you take a close look, there is much more that can be done.

We need to respond meaningfully to the pressing environmental issues. One response is to build much more energy efficient houses. We have the ability, understanding and means build homes that use much less energy and fewer resources than even the better quality homes today. R-2000 should be considered as only a starting point. We can go much further than that.

We also need to tackle consumer expectations. As an industry, we need to find a way to show consumers that you don't need quantity (i.e., lots of square footage) to get quality. Good quality can be provided in more modest compact packages that are not only energy efficient, but also more resource efficient. Our industry has pandered to and helped mould the image that consumers have, expecting more of everything. It's time to reverse that trend.

Let's find a way to deliver what we preach - homes that are energy efficient and built in an environmentally friendly way.

Richard Kadulski,
Editor

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Building with Straw

The rebirth of interest in traditional construction techniques, in part a search for new sustainable construction approaches, means that many people are looking at "alternative" construction materials. Cobb, rammed earth, and straw bale are just a few of the approaches being revived. Each has its aesthetic and technical features. However, it is important to remember that each also has its technical and practical limitations.

Straw bale construction is an option that has attracted wide attention. Straw is a natural, affordable, and annually renewable building material that has been used to shelter people around the world for thousands of years. Straw bale is simply one of many options for more sustainable construction. Its use depends upon accessibility to surplus bales.

Building with bales is a North American approach that emerged with the invention of the horse-drawn baling machine in the 1880s. Perhaps the highest profile straw bale homes are a series of 100-year-old pioneer houses in Nebraska, a dry area.

It is important to recognize that there are significant differences between straw bale and standard frame construction. A major difference is the lack of a vapour barrier on the interior and the absence of exterior sheathing in straw bale. The parging and stucco are applied directly to the straw bale wall. As a result, moisture build-up is possible.

High and sustained levels of moisture can have negative effects in at least three ways. First, prolonged wetness could cause structural damage. Second, mould growth associated with cellulose-based materials can cause serious health problems. Third, high levels of moisture reduce straw's insulation value.

Do we know enough to build stuccoed straw bale houses anywhere? We think not. Straw bale should not be used where there are concerns with stuccoed wood frame buildings. That includes a lot of coastal areas.

Perhaps straw may rot no worse than wood when equally wet and warm, but a stuccoed straw bale is not as moisture-load tolerant. The drainability and breathability of most wood frame walls is generally much better.

Whether straw, cobb, rammed earth, or wood frame, we have to design building envelopes with the underlying thought that water will penetrate the exterior cladding, so the system should be able to accommodate incidental moisture. Water will get in, so it must be able to get out without damaging the structure.

Compared to standard frame construction, straw bale walls generally incorporate higher permeance (more "breathable") interior and exterior protective layers. Although breathability of a wall can refer either to air movement through the wall or moisture movement, it commonly refers to moisture diffusion and not air movement. Much theoretical discussion about straw bale houses centres on the healthfulness of this breathability, but there is not much information available on the subject. Most of the straw bale houses built to date are in warmer arid climates where moisture concerns are easier to deal with because of dry conditions. To satisfy regulatory authorities, technical research on straw bale construction has concentrated mainly on the structural capacity and thermal resistance properties of straw bales.

The high vapour permeability properties of a straw bale wall means that it has the capacity to absorb moisture, and diffuse this moisture to either the exterior or interior of a structure. However, this capacity must not be used as an excuse for inappropriate designs and applications. Remember that vapour diffusion through interior finishes, good vapour retarder or not, does not move large quantities of moisture into the wall. If there is wall moisture from indoors, it can be tracked back to air leaks moving air through the wall and driven by sustained pressure differentials

Although straw bale houses do not use a traditional vapour barrier, they must still be airtight. A straw bale house, when properly plastered outside with cement-based stucco, and inside with cement stucco or wet plaster, will not offer many air leakage points, unlike drywall which often has gaps under the trim details. In straw bale construction, it is the plaster finish that is the air barrier. But as in conventional frame construction, airtight detailing must be followed to achieve airtightness.

Airtightness tests of several Nova Scotia straw bale houses proved that air sealing techniques can be applied to any building material. The tightest house was built by owner/builders who had paid special attention to air sealing in such areas as the wall/ceiling junction, the light and plumbing penetrations into the attic space and the spaces

between the window units and the rough openings. However, it registered 3.13 air changes per hour (the R-2000 limit is 1.5 air changes).

Moisture issues in mainstream housing range from the common use of wet or unseasoned local lumber to foundation leakage, poor site drainage, drywall nail pops, leaks, floor squeaks, truss uplift and condensation problems. Poor installation of air and vapour barriers leads to deterioration of wall, ceiling and floor materials and finishes, excessive moisture in crawl spaces due to 'rising damp', and high humidity related to poor ventilation of living spaces. Straw builders have to deal with all of these issues plus ones that are specific to straw: liquid moisture penetration, potential freeze/thaw spalling of exterior stucco finishes resulting in water damage.

Generally, the moisture in a wall is outdoor moisture penetration. Entrapment of exterior moisture guarantees trouble when the straw is wetted, because straw dries slowly. The straw could stay too wet into the warm weather, and rot in a few years. Mould growth can occur at temperatures as low as -5°C, and at humidities as low as 62%, although the optimum temperature ranges from +20°C to +28°C, and at relative humidity (RH) levels of more than 95%.

Testing Straw Bale Wall Moisture Near the Exterior Plaster *by Habib John Gonzalez*
Monitoring Straw Bale Moisture *by Rob Jolly*
Moisture in Straw Bale Housing, Nova Scotia *S.H.E. Consultants*

Design Considerations

The prime design consideration must be to protect the straw from exterior wetting. When designs are inappropriate, straw bale walls can fail, even in dry, low precipitation climates. Successful designs incorporated combinations of the following strategies:

- the use of verandahs, oversize gables and overhangs for direct control of precipitation
- standard-size gables and overhangs with a combination of other factors including:
- protection afforded by topography and vegetation
- minimal wind driven precipitation
- infrequent exterior wetting accompanied by prolonged drying cycles
- cement-based parging used on exterior and interior
- bales elevated above grade to eliminate backsplash

Designs which produced borderline or unacceptable moisture readings included:

- minimal or no overhangs
- no capillary break between foundation parging and above grade stucco
- structures subject to extreme exterior wetting without drainage
- bales placed below-grade
- inadequate backsplash protection.
- northern exposures

The exterior of straw bale walls is faced with stucco, an absorbent material, which is intimately connected to thousands of tightly packed, poorly draining wicks - straws - embedded in it and leading inwards. When the construction is located in a region with frequent wind driven rains and weak drying conditions, there will be problems.

Because of the increasing interest in straw bale construction, the CMHC has supported the monitoring of several straw bale houses in various parts of the country. Results show that straw bale houses can be designed and built to function properly, but that moisture is also a concern.

Taking measurements in straw bales is not easy. Part of the CMHC studies involved assessing tools to make the measurements. Measuring the relative humidity inside a bale was one technique used. Another was inserting a block of wood with wood moisture pins. The assumption was that the wood would establish moisture equilibrium with the surrounding straw, so the readings would reflect the moisture content.

Although both measuring techniques have their limitations they do provide a reasonable indication of moisture content.

The straw bale houses examined were in a variety of climate zones: Southeast British Columbia, in the semi-arid region of the Okanagan Valley; in Alberta, on the west coast of Washington, as well as in Quebec and Nova Scotia. All buildings displayed seasonal and random fluctuations in moisture readings. Although daily variances in RH are not an indication of straw degradation, prolonged high RH values (over 85%) generally indicate a problem.

Walls seem to have two peak 'wet' times: one in late winter and one in late summer/early fall. This matches the pattern of moisture collecting in a house during the heating season, dispersing over the spring/summer when windows and doors are open and fewer moisture-producing activities are confined to the interior of the house. The summer peak, which is higher than the winter peak, is indicative of the higher absolute moisture levels experienced in the summer months.

The results suggest straw bale walls do not have any unique propensity for moisture retention, but some walls examined, especially north walls, had moisture content readings of 14%-17% during the summer months. These levels suggest borderline to unacceptable conditions. Walls with a southern exposure were generally much drier than walls with other orientations and could handle significantly more exterior wetting.

Two Alberta houses had sustained higher moisture readings and observed indicators that would be considered borderline acceptable. High moisture readings were accompanied by straw samples that were wet and decomposing. In both cases, the problems were the result of two or more design flaws.

The third questionable case was a straw bale house on the west coast of Oregon. The sustained high levels of moisture in the north wall were the result of high atmospheric humidity levels, and not from external wetting.

In one house, areas of damp, slowly rotting straw were found under poorly built windowsills, even under a three-foot roof overhang (but which was two stories above). Some water may also have seeped down from condensation on the indoor glass surface.

In another house, problem areas were one foot above the slab-on-grade. The straw was found to be damp, dark and musty, slowly rotting in a ten-year-old wall. The source of moisture was "rising damp" which is ground moisture wicking through the concrete slab-on-grade that did not have a polyethylene or other effective ground cover. The amount of water rising was greater than the amount of water that could dry, so the straw was rotting from the slab upward.

Houses in Pompeii had slate damp-proof courses near the base of all masonry walls; are we super-slow learners?

Is straw bale construction only for rural applications?

The image of straw bale houses with their thick walls being suited only to rural or large suburban properties is being challenged by Julia Bourke, a professor of architecture at McGill University. She recently completed her own straw bale house on an infill lot in downtown Montreal.

The house is a 2 x 4 timber frame structure with bales packed between the struts as insulating infill. The straw was covered with a 4 to 5 cm stucco coat inside and out.

Prior to installation, a straw bale must be tested ensure that its moisture content does not exceed 11 or 12%, and must be kept dry during construction.

Building code issues remain problematic, as not all building officials will be comfortable with straw bale construction and may require engineering sign-off. There is also the issue of bale size. Straw bales are large, so a wall can be up to 2 feet thick, which can result in less usable floor space on a small lot.

Air Leakage Areas

Most air leakage points found in the four Nova Scotia straw bale houses examined are the same as those found in conventionally built houses. They are not inherent to the process of straw bale construction, except that there seems to be a higher ratio of owner/builders to professional builders. (All four of the houses tested were owner-built). Major air leakage areas were:

- at some electrical outlets on exterior walls where interior plaster was cracked or pulled away from the electrical box.
- testing holes and/or 'truth windows' without glass in front of the exposed straw.
- at gaps/cracks at the top of wall to ceiling/rafter connection
- at window frames at the connection between the frame and the rough buck or straw where no silicone or latex caulking was used to seal the opening at the buck/stucco connection.
- at the connection between door bucks to door and/or window frames
- plumbing penetration through exterior wall and/or through slab
- a handmade door/latch
- an attic hatch
- HRV ductwork in attic (one house)
- potlights in ceiling penetrating to attic.

Are there advantages to straw bale construction?

The most controversial issue is affordability. Proponents suggest there is a cost advantage, but there is no real cost advantage in building with straw - apart from the fact that you can use unskilled labour for a great deal of the work. Costs can range from $50 to $75 per square foot, and depending on finishing details can run over $95 per square foot.

- While the bales go up quickly, the plastering process is slow and requires skill.
- If locally available, the raw materials may be relatively cheap to buy.
- Straw bales are sound proof, reducing noise from outside, and make a building feel very solid inside.
- Plastered straw bale construction has excellent fire resistance. Studies have shown that plastered straw bale walls provide a two-hour rating.
- It is aesthetically pleasing because you can round off or soften edges, and make things like wide casements.
- Dry straw walls can make for a healthy home because of the high insulation values. The natural materials do not off-gas synthetic products.

ISOBORD Engineered Strawboard

Straw can be used in more ways than as a structural or insulation product in walls. Several engineered straw board products are manufactured around the world. In Canada, ***Isobord*** is an engineered board that has been available since 1998. It is made in Manitoba from finely chopped residue wheat straw and non-formaldehyde isocyanate resins, so formaldehyde emissions are not an issue.

Before ***Isobord*** manufacturing started in Elie, Manitoba, farmers burned off residue straw in their fields, creating air pollution problems in the Red River Valley area. Now, the Isobord Enterprises plant uses up to 200,000 tons of the straw each year and has helped alleviate this pollution problem.

Isobord's smooth surface makes it ideal for laminates, foils and hardwood veneers. It is a premium panel with superior properties of elasticity, internal bond, density and strength with no harmful emissions. These qualities mean that Isobord is suited for normal or sensitive applications in both residential and commercial settings. It can be used in many of the same applications as medium density fiberboard, such as countertops, shelving, cabinetry and as a component in furniture and flooring. The company also manufactures StorageBord™ and ShelfBord™ which are straw board products sold directly to consumers through retail outlets.

Isobord is lighter in weight than Medium Density Fiberboard (MDF), and the 1.2 by 2.4 m (4 x 8 ft) Isobord panels come in a variety of thicknesses.

Isobord is not considered a building product like oriented strand board or plywood.

Plans are underway for the startup of several additional Isoboard manufacturing sites in North America over the next few years.

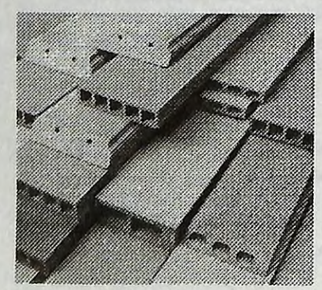
Sales Office: 503-242-7345
http://www.isobordenterprises.com

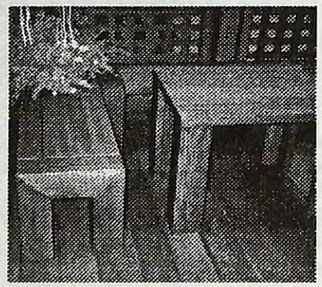
Superwood: a Synthetic Composite Wood

If we are to protect our global environment, we have to use resources efficiently. Using products that contain post-consumer, recycled materials should be encouraged. Fortunately, manufacturers are starting to develop such products.

One interesting new composite wood product has been developed by EIN Engineering, a Japanese company. Its raw materials are wood fibre and plastic (polyethylene, polypropylene, ABS or PVC) which are pulverized, then combined to make a synthetic wood called Superwood.

Unlike the plastic wood we see in North America, Superwood boards are not heavy, solid slabs of plastic with limited structural strength. Instead, the boards are lighter, structurally hollow extruded sections. The wood fibre content helps reproduce the look and feel of high-grade natural wood. This synthetic wood does not need finishing if dyed during the production process, and can be finished in a variety of colours. The planks can also be worked and painted.





The material is heat, water and cold resistant. It retains its structural properties and water resistance even after prolonged exposure. Unlike conventional plastic lumber, it maintains its dimensional stability and does not weaken at temperatures up to 120°C (a dimensional stability similar to aluminum). The manufacturing process used allows the product to be used outside without excessive UV deterioration.

I was impressed with the high quality finish of the material. It meets the exacting standards of traditional Japanese wood joinery, and is being promoted for applications such as exterior decking, railings, trim and furniture. EIN Engineering is also working to develop a thermoplastic plywood-type panel that could reduce or replace reliance on plywood made of tropical hardwood.

Japan is responsible for the cutting of vast amounts of rain forest, and consumes the equivalent of half the forested area of Japan each year! So products like Superwood are a step in the right direction.

Superwood is convered by worldwide patents. Negotiations are underway to set up North American production in Ontario next year.

Measuring Backdraft for Health and Safety

While pressure balance within a house is important to maintain healthy conditions, most houses are subject to pressure imbalances. Depressurization can actually be fatal if there are older, naturally aspirating (open vented) combustion appliances that may backdraft flue gases including carbon monoxide.

Older houses may be especially vulnerable, since rising energy costs prompt homeowners to caulk and seal and replace some naturally vented appliances with sealed combustion units to reduce energy use. Large exhaust appliances such as down-draft cooktops may add to depressurization.

It is important to recognize that pressure distribution in a house can be uneven. A small closed basement furnace room with inadequate return or combustion air can sustain significant pressure imbalances. The carpet staining found around outside walls in many houses is a visible sign of pressure imbalances between the basement or crawl space and main floor.

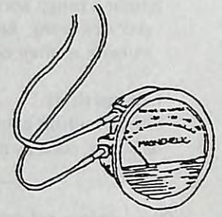
Combustion gases are meant to be vented through a chimney. The draw up a flue is created by the "chimney effect" or buoyancy of warm air that creates a low air pressure in the venting system of a combustion appliance. In a properly operating combustion appliance, air is drawn into the draft hood and up the chimney. A quick check for backdrafting at the draft hood can be done with a match test. In a properly operating combustion appliance, the flame and smoke from a match held near the opening of the draft hood should be drawn into the hood. Remember that combustion appliances may take up to one minute to establish a draft.

Backdrafting can be caused by a blocked chimney or a pressure drop inside the house. If the air pressure in the room where the combustion appliance is found is lower than the pressure in the chimney, combustion gases will spill into the room. That is why it is important to measure the air pressure difference between the room with the combustion appliance and the outdoorst.

To reduce the potential for backdrafting, the building code sets limits for allowable depressurization in new houses. If natural draft appliances are present, the depressurization should not be more than 5 Pascals (0.02" water gauge). Most gas-fired domestic hot water heaters used today are naturally drafted.

Testing for backdrafting

Paul Tschida, an energy education specialist with the Montana Department of Environmental Quality, has developed a kit that is loaned to homeowners who want to check on the safety of their home. The kit's components are readily available: a Dwyer magnahelic gauge and two plastic tubes.



We've reproduced the instructions here, because this is a simple test that anyone can do if there is any doubt at all about pressure balance. Renovators especially should keep the following instructions as part of their toolkit when assessing the condition of houses, before and after a renovation, to ensure safety is maintained.

1. Get the house ready for testing.

All exterior windows and doors should be closed.

Combustion air sources should be left open. Make sure the inlets are not blocked by snow, leaves or debris.

Turn off all exhaust appliances (bath and kitchen fans, clothes dryer, etc.).

Heating systems such as furnace, wood stove and fireplaces should not be operating. Turn down the thermostat if necessary so that the heating system will not start during the test. Fireplace dampers should be closed.

2. Prepare the gauge

The gauge only reads accurately when level and in a vertical position.

Adjust the indicator dial to zero by turning the small screw on the front of the gauge. The dial may require a little adjusting. If necessary, gently tap the side of the gauge and readjust to zero.

An accurate reading cannot be taken if the wind is blowing more than 10 miles per hour because of fluctuating pressures on the building.

3. Set up the tubes

Insert one end of the first tube into the upper connection (high-pressure tap) and run the other end to the outside, going under an exterior door or through a window. Be careful not to pinch the tube. If the tube goes through a window, you may need to use masking tape to cover any gap. The best location is usually the corner of a door.

Put one end of the second tube onto the lower connection (low-pressure tap) and run the other end into the room with the combustion appliance; or put the gauge in the space with the combustion appliance and leave the lower tap open.

If the dial on the gauge is not stable, it is too windy for an accurate reading. If the dial moves to the left, it shows a positive pressure, which is not a backdrafting concern. As the needle moves to the right, it indicates the amount of depressurization. (Every 0.02" is the same as 5 pascals. A reading of 0.1" means a 25-pascal negative pressure).

Negative pressure in a building can be caused by exhaust fans, heating system duct leakage, and in cold weather, by stack effects.

4. Check for negative pressure caused by exhaust fans

Open all interior doors. Turn on exhaust equipment in sequence and note the pressure reading on the gauge each time you turn on a fan. You may want to start with the smaller fans and work up (i.e.: bath fans, kitchen fan, and clothes dryer).

Record the pressure reading as you turn on each fan:

Bath fans _____

Kitchen range hood _____
(recirculating kitchen fans do not vent to the outside so they can be ignored).

Clothes dryer _____

Other venting equipment that draws air out of the building, such as a central vacuum cleaner

_____

One or more exhaust fans or appliances in combination may cause a negative pressure. If the gauge shows 0.02" W.G. or more negative pressure, it is probable that the combustion appliance(s) will backdraft. Under some circumstances backdrafting may occur at less than 0.02 inches of water column negative pressure.

If a problem is found, some means of providing make-up air is needed. Try opening a window located close to the exhaust fans causing the negative pressure, then watch the gauge. Allow enough make-up air to reduce the pressure to less than 0.01 inch of water column negative pressure. For a permanent solution, mechanical make-up air may have to be provided.

Return all exhaust fans to their normal position.

5. Check the effect of a forced air heating system.

Close all interior doors. This restricts airflow to the return side of the furnace, which may increase the negative pressure at the combustion appliances. Repeat the reading.

If a combustion appliance is located in a crawlspace:
- Close crawlspace vents if they are normally closed in winter
- Close the crawlspace access door.
- Turn on the heating system.

Follow the steps in "Prepare the gauge" above.

Negative pressure is often caused by duct leakage on the return side of the heating system. Repairing the return side duct leakage should solve the problem. A missing furnace filter, access cover and furnace cabinet leakage also can contribute to negative pressure.

If the negative pressure is caused by insufficient airflow back to the furnace, try opening interior doors and watch the gauge. Although doors should be undercut, the undercut may not be enough to balance airflows. Relieving the negative pressure requires installing pressure relief grills between rooms with supply registers to allow air flow back to return air registers. An HVAC contractor may be able to supply other solutions.

Do a final test of total negative pressure with all exhaust fans and heating system operating.

Healthy Indoor Environments

We spend most of our lives indoors, inside vehicles, offices, restaurants, shopping malls, skating rinks and houses. Despite the progress being made, evidence suggests that many of these indoor environments are continuing to damage the health of the people working and living in them.

In the United States, indoor pollution causes thousands of cancer deaths and hundreds of thousands of respiratory health problems each year. A recent report on asthma and indoor air quality linked indoor exposures to the development and provocation of asthma.

eading authorities such as the American ung Association, the United States Environmental Protection Agency (EPA), CMHC and others have consistently identified indoor pollution as one of the most serious risks to human health. Unfortunately, pollution in Canadian buildings of all types has received insufficient attention from government agencies, corporations, other organizations and individuals. We have no clear structures or national strategies for addressing indoor air quality problems, and, with few exceptions, no acknowledged government or community leadership on this complex issue.

Sick building syndrome incidents are still common. Many materials, furnishings and commercial products continue to pollute our indoor environments. Buildings are still being built, renovated and maintained without adequate attention to indoor environment issues.

Healthy Indoors is a cross-Canada, consultation, strategy development and alliance building process for achieving healthy indoor environments. A discussion paper has been prepared to provide a common level of information and analysis of the issues involved and options available to achieve the objective of improving the indoor air quality in our indoor environments.

Background papers available for download are at: *www.healthyindoors.com*

Forums have been held in Toronto and Halifax. The next one will be in Vancouver March 1, 2001. The intent is to bring together policy makers from various sectors to develop a strategy. Anyone with a concern for indoor air quality is encouraged to look at the papers, submit their comments and participate in the process.

You Asked Us: About Window Installation Details

In the article on "*Wall Moisture Problems in Alberta Dwellings*" (September 2000 issue of Solplan Review - No. #94) you suggest a way to peel and stick a window at the bottom. I am not sure what you mean.

I read it as: first, you install a strip of (notched) peel and stick into the window opening at the bottom and then install the window. Second, you lap the sides and top with the window flange to the plywood sheathing. Finally, you put another piece of peel and stick over the bottom of the window flange and over top of the building paper. Have I read it correctly?

This is an important detail, and a source of many problems in construction. It does not help that window manufacturers have been slow to recognize the problem, and have not been willing or able to offer installation instructions for their products.

Yes, you first put the peel and stick, then the window. The sheathing paper should then be lapped by shingling over the top, always in a way that any water that will penetrate the surface will be shed, rather than work its way into the wall. But the peel and stick should be applied overtop the sheathing paper. You should not use two layers of peel and stick, and the peel and stick should not be placed directly on the wood.

The peel and stick should only go on the sill and 6 inches or so up the jamb. Evidence suggests that you do not want to use much peel and stick at the window head - where there is much wood. Wood pieces can have large quantities of moisture inside, even if the surface measures less than 19% moisture content. This moisture has to dry, and will move outward over time. Peel and stick directly on the wood will trap the moisture and contribute to rot.

These illustrations show the procedure for installing the sheathing paper around a window opening.

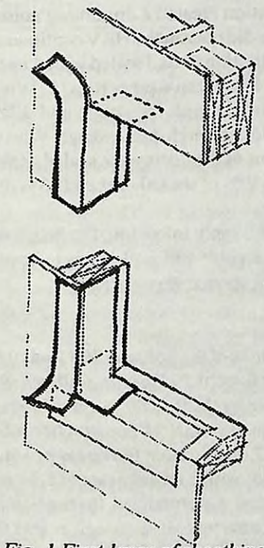


Fig. 1 First layer of sheathing papers lapped and installed on rough opening.

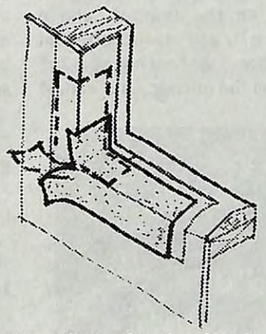


Fig. 2 Strip of peel and stick applied over sheathing paper, at window sill area. Vertical strip applied over lower strip, and NOT up full height of jamb. Alternative to "peel & stick" could be Tyvek Flex Wrap

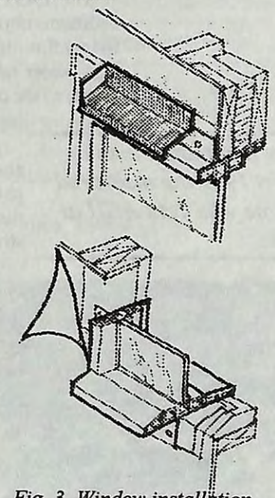


Fig. 3. Window installation. Head flashing with end dam. Note lapping of sheathing papers. The next step would be sheathing paper over head flashing, then strapping for exterior cladding support.

West Coast R-2000 House: Airtight and Dry After 17 Years

Richmond, BC R-2000 House Case Study

Claims have been made that recent building envelope problems on the West Coast are the direct result of energy efficient construction practices. High insulation levels, polyethylene air and vapour barriers and airtight construction in a mild, wet climate have been said to be a cause of envelope failure.

Examination of one of the first R-2000 houses built in BC has shown that, after 17 years, there is no evidence of deterioration or moisture problems. A 250 sq. ft., one level addition to a R-2000 home built in 1983 offered an opportunity to review the durability of construction practices used.

There was no evidence of any moisture within the wall structure. Wood moisture content readings in the wall framing were 11 - 13%, well below the 19% moisture content considered the threshold for fungal action. By comparison, the new framing lumber being used for the addition had a moisture content of 15 - 20%.

After 17 years, the wood moisture content in the wall framing was 11 - 13%

The 1,433 sq. ft., two storey house has two bedrooms plus den, two bathrooms, and open plan living/dinning/kitchen area. The property has a high water table, about one foot below finished grade, so the concrete slab-on-grade foundation is insulated under the entire slab.

The house had maintained its air seal. In 1999 the measured leakage rate was 1.33 ACH at 50 Pascals.

Exterior walls are 2x6 with plywood sheathing on the exterior, and a polyethylene air and vapour barrier on the inside face of the framing, plus 2x3 strapping on the interior. The vaulted roof is framed with R-28 batt insulation.

South side of house, after addition.

The polyethylene air and vapour barrier appeared as good as the day it was installed (before the availability of UV stabilized poly). The sheathing paper was in good condition, although the vinyl siding was applied directly with no rain screen. arge quantities of acoustical caulking were used to achieve the air sealing. The caulking was still soft, pliable and had kept its adhesive properties.

Heating is by electric baseboards, while domestic hot water is provided by a standard gas-fired hot water tank - the only vented combustion appliance in the house. The homeowner did complain of cold drafts in the area next to the hot water tank. An uninsulated 4" combustion air duct drops straight down, ending 24" above the floor adjacent to the water tank, with no spillage protection or trap.

Ventilation is provided by a heat recovery ventilator. The HRV was inside the heated envelope of the house, but placed on top of the ceiling joists in the attic. Although the HRV was set on a foam pad, fan motor vibration created a drumming noise, so the homeowner did not run the HRV continuously.

Ducts were friction fit and sealed with duct tape which had lost its adhesive properties. 42% of the exhaust air flow through the ducts, and 17% of supply air was lost through duct leakage. When the exposed portions of the ducts were sealed, leakage was reduced to 30% of the exhaust and 13% of the supply air flow.

Exhaust and Supply inlets into the house were placed high on a gable end wall, 20 feet above the ground, making service very difficult.

Airtightness

The airtightness of the house in 1983 was 0.889 air changes per hour at 50 Pascals, well below the 1.5 ACH limit set by the R-2000 technical requirements. A test at the start of construction of the addition in 1999, showed that the house had maintained its air seal, with a leakage rate of 1.33 ACH at 50 Pascals, and a normalized leakage area of 0.60 cm^2/m^2 of envelope area (which is less than the R-2000 limit of 0.7 cm^2/m^2.) Some of the difference can be attributed to how the house was set up for the test.

Construction Characteristics

Element	Standard Practice, 1983	As Built, 1983
Ceilings	R 20	R 28 batts
Walls above grade	R 8 batt (2x4 @ 16" o/c)	R 28 (2x6 @ 16"o/c plus 2x3 strapping)
Windows	Single glazing aluminium frame	Clear double glazing, thermally broken aluminium frame
Skylights	Single glazing, glass or acrylic	Double glazed acrylic
Exterior doors	Solid wood	Metal insulated
Slab-on-grade	R 4 along perimeter, slab uninsulated	R 10 under entire slab plus R 10 along exterior of foundation wall
Airtightness	No attention to airsealing	0.889 ACH at 50 Pa (R-2000 requirement = 1.5 ACH @ 50 Pa or NLA of 0.7 cm^2/m^2)
Air and vapour barriers	2 mil poly v.b. no special air barrier	6 mil poly v.b. caulked and sealed for air and vapour barrier
Heating	90,000 BTU gas furnace	Electric baseboard
Hot water heater	gas hot water heater	gas hot water heater
Ventilation	no ventilation	Heat Recovery Ventilator

Most of the air leakage was around the hot water heater B-vent, a sliding patio door, HRV vents, and an opening bathroom skylight.

Temperature stratification

In a well sealed, well-insulated building the stack effect should not be pronounced, and temperature stratification should be minimal. However, the owner did notice cooler temperatures on the lower floor, which were solved by installing a ceiling fan over the vaulted living area.

The house was leakier after the addition was completed. The increased leakage came about due to less attention to the air sealing details around a new direct vent gas fireplace, recessed pot lights, and a new skylight. The increased leakage contributed to a greater stack effect which was noted on a day with an outdoor temperature of 1°C. With the new direct vent gas fireplace as the only operating source of heat in the house, a 5°C temperature difference was observed between the floor level of the main floor and the ceiling of the second floor.

Energuide Evaluation

The house as renovated received an Energuide rating of 79 on a 100-point scale. An energy efficient house meeting R-2000 technical standards should rate between 80 and 90. A typical Vancouver area house built in 1983 would have a rating of 60 to 75.

HOT-2000 Energy analysis

The original energy performance analysis for the house done in 1983 showed a simulated energy consumption of 12,396 kWh per year, or 12.5 % less than the R-2000 compliance target. Using the current more refined HOT-2000 compliance tool, the simulated consumption is 11,709 kWh/yr or 10.3% less than the 13,068 kWh per year target. Actual energy consumption meets the predicted consumption.

R-2000

For information on the R-2000 Program, contact your local program office, or call 1-800-387-2000

Canadian Home Builders' Association

Technical Research Committee News

Proposed Minimum Window Performance Requirements

NRCan has released a draft proposal to regulate the thermal performance of factory-built windows under the Energy Efficiency Act. Products to be covered include:

- residential windows;
- non-residential windows;
- flat-glazed skylights;
- roof windows; and
- sliding glass doors.

The proposed minimum energy efficiency standard for residential windows is an Energy Rating (ER) of -13 for operable products and -3 for fixed products.

For flat-glazed skylights and roof windows, the total window U-value must be 3.1 W/m²C or less (RSI 0.322 or R 1.82).

Labelling Requirements

As part of the requirements, it is proposed that an appropriate EnerGuide label must be put on every unit. The format of the labels is still under development, but it is suggested that each label show the ER or U value for that product, which can be derived by testing or computer simulation.

To be able to enforce the proposed regulations, each unit will have a permanent Product Identification Mark (PIM). The PIM is analogous to a model number and would ensure that documentation can be related to a specific product.

The proposed date for the prescribed labelling of products is June 1, 2002, and the date for meeting the minimum energy requirements is September 1, 2003.

What You Should Know About Window Performance Ratings

Windows come in different types and materials. Windows provide ventilation, light, a view to the outdoors, and a part of the a building's overall aesthetics of a building. They are also part of the building envelope of the building, so they must resist water and wind. Since one-third to one-half of a home's heat loss can be attributed to windows, energy performance is also an important consideration for controlling home heating costs.

With thousands of products to choose from, how can you be sure you are getting good value? Choosing appropriate windows requires more thought today now than was the case in the past. Besides energy ratings, other performance factors apply to windows. These are part of the CSA A440 Window Standard.

Products with the CSA mark have been tested and certified to relevant performance standards relating to:

* air tightness (A)
* water tightness (B)
* wind load resistance (C)
* forced entry resistance (F)
* screen strength/ease of operation (S/E)

"optional" performance standards are:

* condensation resistance (I)
* energy rating (ER)

It is important to recognize, however, that the CSA tests are done on a "design" unit supplied by the manufacturer, and no ongoing, random sampling program is in place to ensure that production models meet design specifications. This means that the units delivered to the site may perform better or worse than the units officially tested units. In addition, the performance of a window's performance will depend a great deal on how it is installed. Price is not always an indication of performance or quality.

Performance Ratings

Air Tightness (A)

The performance rating for air tightness of windows and sliding doors is represented by the letter 'A'. The air tightness test measures how much air would pass through a closed window or sliding door at an air pressure differential that represents a wind speed of 40 km/h (25 mph).

Performance is shown by a number rating from A1 to A3. The higher the number, the more airtight the product. For example, a window with an A1 rating could have an air leakage of 2.79 m³/hr-m (or 0.5 cfm per foot of perimeter). An A3 rating could be 0.55 m³/hr-m (or 0.1 cfm per foot of perimeter).

Water Tightness (B)

Water tightness is represented by the letter 'B'. Water tightness testing involves applying a uniform water spray at increasing air pressure (to simulate wind-driven rain) until water penetrates through the window or sliding door. Performance is shown by a number ranging from B1 to B7 for windows, and from B1 to B4 for sliding doors. The higher the number, the more watertight the product. A B1 rating means leakage can occur at 137 pascals (0.55" WG), while a B3 resists 250 pascals (1" WG).

Wind Load Resistance (C)

Resistance to wind load is a measure of the product's structural strength and is tested by applying increasing levels of air pressure to simulate the wind force. Air pressure is applied until the product's operation is impaired. Wind load resistance is represented by the letter 'C'. There are up to five levels of wind resistance for windows (C1 to C5) and three levels (C1 to C3) for sliding doors. The higher the number, the better the performance. The pressure limit for a C1 rating is 1.5 kPa (31.3 psf) while for a C3 it is 2.5 kPa (52 psf).

Condensation Resistance (I)

This test is optional so not all certified windows and sliding doors are tested for condensation resistance. Condensation resistance for windows and sliding doors is determined by a thermal characteristic called Temperature Index (I), which ranges from 40 to 80. The higher the number, the more likely the product will resist condensation.

Condensation is influenced by outdoor winter temperature and the indoor relative temperature and humidity. Very few windows or sliding doors will be free of condensation if the indoor humidity is higher than 40% at outdoor temperatures of -20 degrees Celsius or less.

Forced Entry Resistance (F)

The standards for windows and doors include a test to suggest how well the product may thwart entry within five minutes. One of two ratings is assigned, F1 or F2. For windows, F1 means the product has a lock, while F2 indicates it has a lock and it passes hand and tool manipulation tests. This test is optional for windows that are installed higher than two meters from the ground. All sliding doors must have a lock or latching device. An F1 or F2 rating indicates the product has passed hand and tool manipulation tests. As with windows, F2 represents the higher level of security.

Screeen Strength/Ease of Operation (S/E)

Sliding doors are tested for ease of operation and the letter 'E' represents the performance rating. Insect screens are not intended to serve any purpose other than to keep insects out. They are tested for tear, damage or retention in windows when subjected to loads. A rating of S2 is stronger than S1. Sliding doors are tested for ease of operation based on the force required to open and close the moveable section of the door. Ratings range from E1 to E3, where E3 requires the least amount of effort.

Energy Rating (ER)

This rating is determined by calculation. It is optional, so not all products are analyzed for energy efficiency. The ER rating for windows and sliding doors considers:

* Solar heat gain
*Heat loss through frames, center centre and edge of glass
*Air leakage heat loss

The combined effect of all three is defined in watts per square metre and can be either a positive or negative number. A positive number represents a net heat gain, while a negative number suggests that the unit loses more energy through heat loss and air infiltration than it gains in solar energy absorbed from the sun.

ER numbers range widely depending on the type of window and design options. Fixed windows generally have better ER ratings than operating windows. Operating windows and sliding doors typically have an ER number ranging from -35 (a very poor energy performance) to +8. Fixed windows can have positive numbers that can be as much as +15.

(Continued next page ...)

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.

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Installation

Poor installation may defeat the benefits of selecting a good window. The CSA A440.4 standard sets out requirements for installation for some types of window units.

* Before installation, windows should be handled with care and stored in a place protected from the weather.

* Window frames should be set plumb and square, properly and well secured to the surrounding structure, and according to the manufacturer's instructions.

* The window sill should be adequately supported and set level, with particular care taken to see that the designed "bevel" or "fall" is maintained to the exterior.

* Windows should not be expected to carry any load other than their own weight nor should they be structurally modified to accommodate air conditioners, exhaust fans, etc.

* Cavities between window frames and the rough opening should be properly filled with insulation.

* The exterior joints between window frames and the building opening should be carefully caulked.

* The full interior of the window should be sealed between the window frame and the window opening to act as an air and vapour seal.

* Where applicable, sash and hardware should be adjusted for smooth operation after installation of the window.

Letters to the Editor

Re: Editorial (Solplan Review No. 95, November 2000)

Thanks for a nicely written editorial in the November Solplan Review. From a builder's perspective, I cannot begin to express the frustration that I feel rising inside of me (not directed at you) as I read your article and feelings that I believe are felt throughout this industry.

In our firm, we have tried not only to be innovative, progressive and customer oriented, but also profitable. The last seems to be almost a heretical concept in Canada. Even with instant communication via cell phones, pagers, two way radios and laptops in our trucks mated to database software and linked through cell phone modems to servers in our office, we still cannot keep up. We have tried working smarter, longer hours, devoted much time to educating ourselves, and been involved at all levels of regulation to implement change.

We still are regulated by putting shoes on our children's feet, maybe even giving them Playstation 2, when available, paying taxes on land, mortgages on model homes and land investments, interest at the bank on our large overdrafts to cover the decorator's fees, the landscape architect, the drapery person, the marketing consultant, and the sign guy, etc. All this so consumers will be wowed enough so that when they make the largest investment decision in their life, based solely, in most cases, on the emotion of the moment, they will pick one of my homes above the other "quality" builder down the road.

While I agree that all trades are specialized, imagine the cost if they were not. How many homes could we sell at those costs? Yes, there are even some bad builders out there. Excuse me for the cynicism, but until the consumer is willing to properly compensate builders for their efforts, investments, reward professionalism and make realistic buying decisions based on reasonable budget restraints and not on "how big, how much"; and government is willing to recognize us as legitimate providers to the economy and not as cash cows for their latest projects, the home buying public will continue to be robbed of some of the best housing technology that is available in the world sacrificed to the god of "keeping all accounts current."

Despite common perception, none of the builders I know are rolling in the bucks. Tight profit margins and no profit margins are the order of the day despite an improved economy. Let us never forget, while the system is not perfect and obviously needs continuous monitoring and improvement, Canadians are still the best housed people in the world.

As you have ably documented in the past, there are numerous issues that continue to hamper our industry. Why is it that despite better products, more detailed research, better designs, etc. we are having more building problems? Another discussion for another day perhaps.

Paul Rawlings
Rawlings Homes
Ontario Home Builders' Association Member of the Year 2000

Re: letter to the editor (Solplan Review No 95, November 2000)

David Hill's letter to the editor raised many points about residential ventilation system distribution strategies. CMHC commissioned a research project 'Field Survey of Heat Recovery Ventilation Systems' in 1995 on this very issue. The work, conducted by Buchan, Lawton, Parent Ltd., used tracer gas decay tests to determine the ventilation effectiveness of many different HRV installation configurations.

The study found that independently ducted HRVs and HRVs connected to forced air systems both worked well in exchanging air and distributing air throughout houses. However, the ventilation effectiveness of the HRV interconnected with the forced air heating system ductwork was dependent on the operation of the furnace fan. HRVs are not capable of forcing air through space heating ductwork systems sized for ten times the airflow - the air simply gets 'lost' in the system. An incidental finding of the study found that an adequate amount of ventilation air could be induced through HRVs connected to the supply and return air ducts of forced air heating systems without the operation of the HRV fans. However, this ventilation strategy was not fully assessed.

Natural Resources Canada commissioned a subsequent study to assess the energy consumption attributable to different ventilation strategies ('*Report on Energy Impact of Ventilation Air Distribution*' prepared by UNIES Ltd., 1995). Not surprisingly, the independently ducted HRVs consumed the least amount of electricity while the ventilation systems made up of HRVs connected to forced air heating systems tended to consume the most due to the continuous operation of the furnace fan. The use of high efficiency ECM motors in the furnaces used to distribute ventilation air on a continuous basis was found to be very cost-effective even with the high cost of ECM motors.

The CMHC study also found that no matter the strategy used, the system performance varied with operation and maintenance habits by the homeowner. The study found that ventilation systems are generally poorly operated and maintained. Many homeowners were not aware of the positive and negative impacts that their ventilation system could have on indoor air quality, building envelope durability, energy efficiency and heating costs. More homeowner education and after sales service support is required as homeowner ignorance can quickly undermine the best ventilation system.

The CMHC 'Field Survey of Heat Recovery Ventilation Systems' report is available, free of charge in Canada, from CMHC's Canadian Housing Information Centre, 1-800-748-2642 or visit on-line at *www.cmhc-schl.gc.ca.*

Duncan Hill
Research Division
Canada Mortgage and Housing Corporation

Re: Energy Answers (Solplan Review No. 95, November 2000)

We would like to point out an error by Rob Dumont in his "Energy Answers" page. In his reply to the second question, he states that about 12 inches of either blown glass fibre or cellulose insulation will provide R-40. This is incorrect.

Blown glass fibre insulation has a thermal resistivity of about R-2.6/inch - R-40 would require at least 15 inches of this material. However, since this low-density product is quite susceptible to convective heat loss (reducing its R-value), as much as 50% more is required.

Cellulose fibre insulation products provide a thermal resistivity of R-3.6 - R-3.8 per inch thickness. R-40 would only require about 10.5 to 11 inches of this product. These products are denser and much less susceptible to air/moisture infiltration and convective heat loss. We would like to see this clarified in the near future.

The importance of ventilating the attic space (to reduce the potential for condensation) should also have been stressed.

Cliff Travis
Quality & Technical Manager
Can-Cell Industries Inc.

Rob Dumont's response is part of his Energy Answers column this issue (page 16).

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Energy Answers

Rob Dumont

Is furnace over-sizing all that big a deal? Won't a larger furnace run less often, and hence use less electricity? (In many parts of the country electricity is significantly more expensive than the fossil fuel being burned.)

Furnace over-sizing is a widespread phenomenon. A major study done for CMHC some years ago by Unies Engineering documented this. We have also found this to be true in some recent work for CMHC that we are doing on retrofitting six houses for energy efficiency here in Saskatoon. The following are the furnace sizes in the six houses, along with the measured natural gas consumption of the house (including water heater use) extrapolated to local outdoor design conditions of -35 °C.

House Code	Furnace Input Capacity (BTU/hour)	Natural Gas Consumption extrapolated to -35°C (BTU/hour)	Ratio
D1	120,000	49,400	2.4
G1	90,000	46,400	1.9
G2	100,000	54,900	1.8
G3	130,000	36,800	3.5
G4	200,000	83,000	2.4
H1	164,000	64,800	2.5
1 kW = 3,413 BTU/h			

As you can see, the house furnaces are all generously over-sized. One house has as much as 3.5 times the capacity needed. Some over-sizing is desirable to allow pickup after night setback and to account for uncertainties in the calculation of the heat loss from the house. But over sizing by 100% is over-kill. I would think that about a 30% over-sizing would be appropriate for most houses.

While it is true that a larger furnace will run fewer hours in a year, it is also true that larger furnaces tend to have larger furnace fan motors. One particularly bad example is a 90,000 BTU/hour furnace on the market that uses a ¾ horsepower fan motor. Most furnaces that size usually use either a ¼ or ⅓ horsepower fan motor. The heat generated from the ¾ hp motor adds 2500 BTU/hour to the air stream and subtracts substantially from your bank account.

Another problem with over-sized furnaces is that they require larger sized ducts to perform efficiently. Newer furnaces generally have considerably higher air flows for the same BTU/hr output than older units. If you replace an older 100,000 BTU/hr furnace with a new mid-efficiency or condensing furnace of the same output, the required warm air flow through the new furnace will generally be about 40% more. The old ductwork usually cannot take 40% more air flow, and the new furnace will not work very efficiently because the warm air flow is reduced.

Small is beautiful. Especially with furnaces.

Is cellulose fibre a better insulator than glass fibre?

Here are some numbers from the CCMC (Canadian Construction Materials Centre, National Research Council of Canada) Registry of Product Evaluations.

Material	R-value per inch of thickness (English Units) (hr-ft²-°F/BTU per inch)	Relative R-value
Loose fill cellulose fibre (average of 10 different brands)	3.75	1.36
Loose fill mineral fibre (average of 10 different brands)	2.76	1.0
1 m²-K/W = 5.678 hr-ft²-°F/BTU		

As can be seen, loose fill cellulose fibre has a greater R value per inch of thickness by 36% compared with loose fill mineral fibre insulations. Thus a foot of cellulose fibre would yield an R value of 45, while a foot of loose fill mineral fibre would have a lower value of R33.

Glass fibre batt insulation, however, has a higher R value per inch of thickness than either loose fill mineral wool or loose fill cellulose fibre insulation. For instance, a 10.4 inch thick glass fibre batt made by Owens Corning has an R value of 3.85 per inch of thickness, and a 5.5 inch batt has an R value of 3.99 per inch of thickness.

Batts and loose fill are thus like apples and oranges–both are good for you; each have different "strengths."

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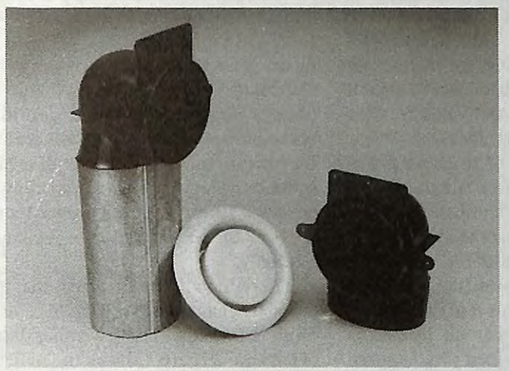

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February 22-23, 2001
8th Canadian Conference on Building Science and Technology by the Ontario Building Envelope Council
Toronto, ON
Tel: 877-235-6232

March 1-4, 2001
World Sustainable Energy Day Conference and Trade Show Wels, Austria
Tel: +43 732 6584 4380 Fax: +43 732 6584 4383
www.esv.or.at

April 30 - May 5, 2001
Affordable Comfort 2001
(Home performance industry's largest conference)
Milwaukee, WI
Tel: 724-223-7750 Fax: 724-223-7754
www. Affordablecomfort.org

June 26 - 29, 2001
International Conference on Building Envelope Systems & Technologies
Ottawa, On
Tel: 613-993-0435 Fax: 613-952-7673
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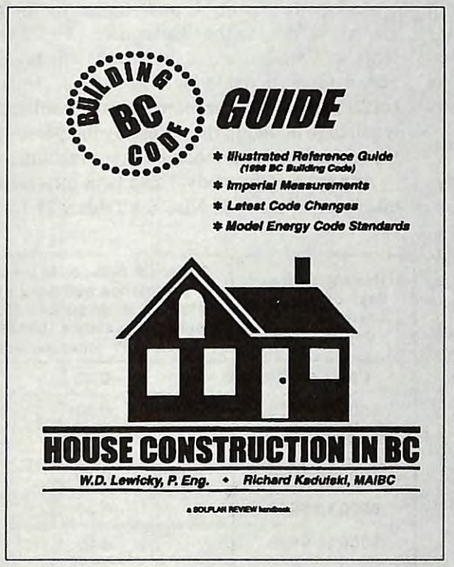
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W.D. Lewicky, P. Eng. • Richard Kadulski, MAIBC
a SOLPLAN REVIEW handbook

A Simplified, Illustrated Guide to Residential Construction in BC

House Construction in BC

by W.D. Lewicky, P. Eng. and Richard Kadulski, MAIBC

The illustrated guide to the 1998 BC Building Code explains Part 9 of the code as it applies to residential construction. This reference guide uses imperial measurements and explains code requirements with sketches where appropriate. The guide highlights the new code changes that came into effect on December 18, 1998.

Editorial comments are made to show where better practice can avoid problems, especially with building envelope detailing.

Also includes highlights of Model National Energy Code for Houses requirements for BC. (These standards are currently optional).

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Avoiding Condensation with Low-Permeance Materials

by M.K. Kumaran and J.C. Haysom

More details on this subject are contained in Construction Technology Update No. 41, available from IRC.

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The 1990 National Building Code (NBC) stated that the air barrier could be a separate component located anywhere in the wall. This change raised the possibility that someone using a low-permeance material as an air barrier might choose to place it close to the outer surface of the wall where condensation could form on its interior face.

To reduce the probability of incorrect placement, the 1990 NBC included a restriction on the location of low-permeance air barriers. These air barriers had to be placed so that the inner surface remained above the dew point of the interior air when the outside temperature was 10oC above the January 2½% temperature. This restriction, however, prohibited the use of certain insulating sheathings that had long been used without problems on the outside face of wood stud walls. Manufacturers argued that the restriction was unnecessary and asked that it be removed in the 1995 NBC. Concerns were also raised about the potential for condensation on low-permeance materials placed towards the outside even if they weren't designated as the air barrier.

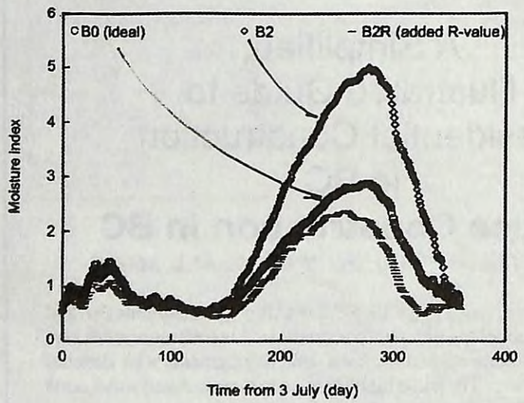

Figure 1. Annual moisture accumulation within the cavity (the moisture index is the daily average on a relative scale).

***Wall B0** – Type II vapour barrier, zero air permeance (no air leakage), interior RH 36%.*
***Wall B2** – Type II vapour barrier, air permeance 0.1 L/(m²·s·75 Pa), interior RH 36%.*
***Wall B2R** – Type II vapour barrier, air permeance 0.1 L/(m²·s·75 Pa), interior RH 36%, low-permeance insulating sheathing with RSI of 0.75.*

IRC Study Solves Problem

In a landmark study, researchers at IRC studied the problem using an advanced computer model developed with colleagues at the Technical Research Centre (VTT) in Finland. Unlike previous models, this model is not a steady-state model but dynamically and iteratively treats the inter-relationships of heat transfer, air movement, moisture diffusion and airborne moisture transport using real weather data for typical years for a number of locations. It can be used to study the effect of changing a building envelope assembly or the properties of its components on the accumulation of moisture within the assembly.

The simulations analyzed the moisture and thermal behaviour of wall cavities for one full year on an hourly basis using weather data for the City of Ottawa. Figure 1 shows the moisture accumulation within the cavity for three of these walls, which are described below the figure.

These results show that condensation was less likely to occur in the wall with insulation on the outside than in the other walls studied. The simulation determined that the ratio of outboard to inboard thermal resistance used (0.75/3.52=0.214) was adequate to control condensation for an interior RH of 36%, in the Ottawa area. Simulations for other Canadian cities showed that the required ratio is proportional to the degree-days. Thus the colder the location, the more external insulation is required to maintain the necessary temperature in the cavity to control moisture accumulation.

As a result of this study, Table 1was incorporated into Part 9 of the 1995 NBC (as Table 9.25.1.2.)

Heating degree days of building location, Celsius degree-days	Minimum ratio, total thermal resistance outboard of material's inner surface to total thermal resistance inboard of material's inner surface
Up to 4999	0.20
5000 to 5999	0.30
6000 to 6999	0.35
7000 to 7999	0.40
8000 to 8999	0.50
9000 to 9999	0.55
10000 to 10999	0.60
11000 to 11999	0.65
12000 or higher	0.75

Using Low-Permeance Exterior Insulation

Where a low-permeance material is used in a wall, the ratio of outboard to inboard thermal resistance must equal or exceed that needed to control condensation.

The thermal resistance of a wall is the total of the resistance of all the materials that make up the wall, such as insulation, sheathings, finishes, air spaces and air films. The inboard thermal resistance is the sum of the thermal resistance of all the materials on the warm side of the low-permeance insulation. To calculate the minimum thermal resistance of the outboard insulation, first the inboard thermal resistance is multiplied by the ratio from Table 1 that applies to the climatic conditions. This result represents the total thermal resistance for all outboard elements including exterior insulation, exterior finish material and air film. Adding up the thermal resistance for all other outboard elements and subtracting this subtotal from the total outboard thermal resistance gives the minimum thermal resistance of the exterior insulation. The example below shows a sample calculation for a wall design in Winnipeg.

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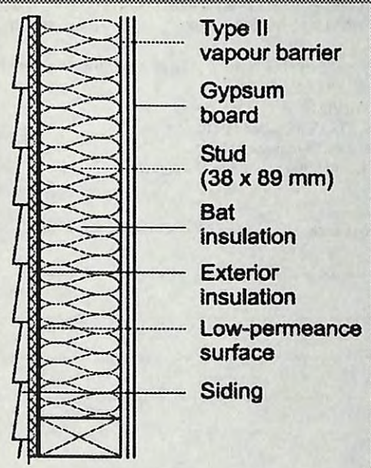
Example

Winnipeg has 5900 degree-days which, according to Table 1, requires a minimum RSI ratio of 0.30. The following calculations show how the minimum amount of outboard insulation would be calculated for a 38- x 89-mm stud wall.

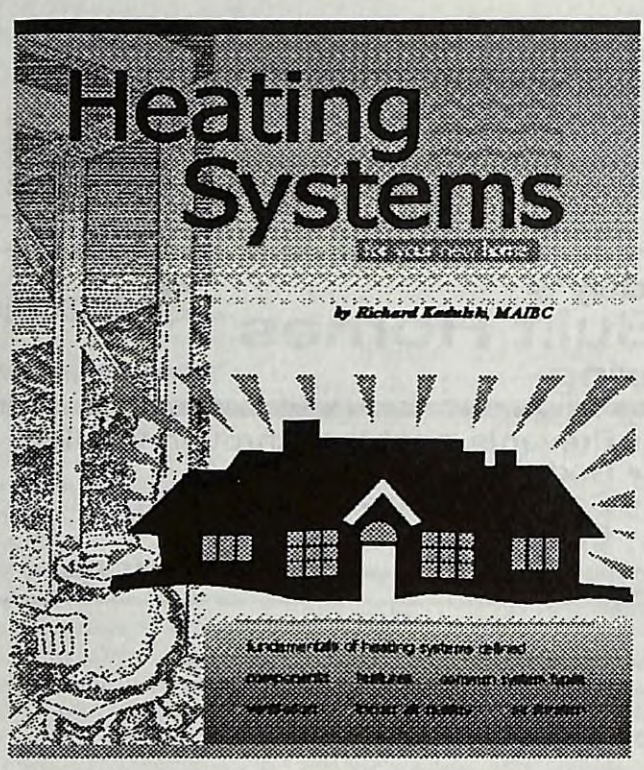


38- x 89-mm stud wall

Inboard thermal resistance	RSI	Outboard thermal resistance	RSI
Insulation	2.11	Insulation to be calculated	
Gypsum board	0.08	Metal or vinyl siding	0.12
Air film	0.12	Air film	0.03
Total	2.31	Subtotal	0.15

Minimum outboard insulation = 2.31 x 0.30 = 0.69
Less siding and air film 0.15
Minimum thermal resistance of insulation 0.54

Total wall resistance = 2.31 + 0.69 = 3.00
(without taking into account thermal bridging through studs)



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